Chapter 7. Canyonlands National Park

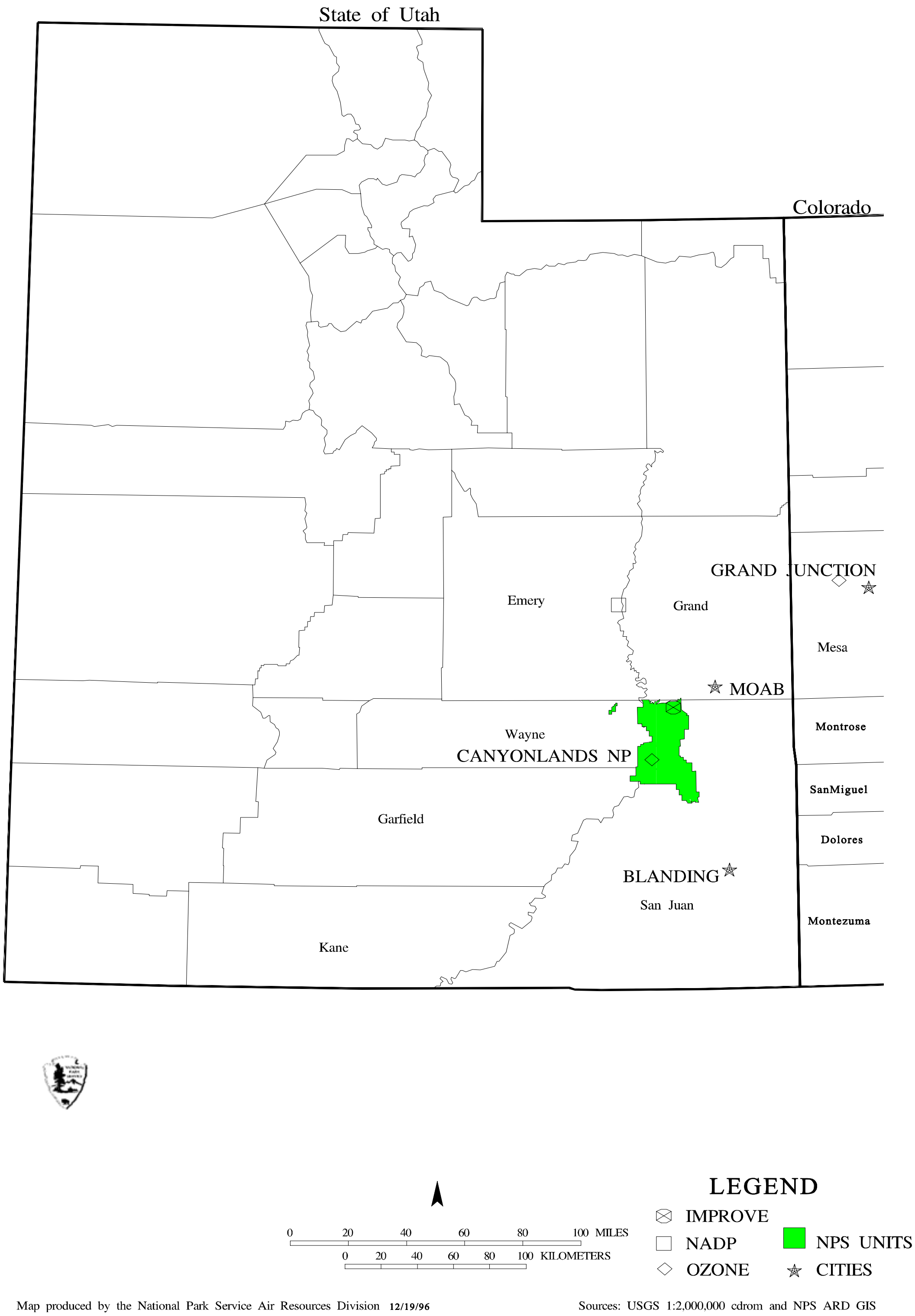
Introduction

Canyonlands National Park was established in 1964 to “protect a remote region of exceptional scenic quality and archaeological and scientific importance at the confluence of the Green and Colorado rivers in southeastern Utah for inspiration, benefit and use of the public". The Park encompasses 136,670 ha of federally owned land in the high desert region of southeastern Utah (Figure 7-1). Elevations range from 1125 m where the Colorado River leaves the Park in Cataract Canyon to 2170 m at Cathedral Point in the Needles District at the southeastern end of the Park. In addition to the spectacular natural beauty, the Park has many archeological features including prehistoric pictographs and petroglyphs and the remains of several Native American cultures. The Park includes parts of Garfield, Wayne, Grand and San Juan Counties.

Geology and Soils

The oldest formations in Canyonlands National Park date back to the Paleozoic Era, when much of the region was covered by shallow seas. These seas deposited successive layers of marine limestone, sandstone and shale, especially during the Pennsylvanian Period. These seas occasionally became landlocked which resulted in evaporation of sea water and deposition of the evaporites. The overall thickness of these alternating salt and shale layers can exceed 1000 m. During the Permian Period, these basins were filled with alternating layers of sand and pebbles eroded from surrounding highlands, and marine deposits (sands, shales, and limestone) from periods when shallow seas advanced over the landscape. The Mesozoic Era brought large scale changes in climate and depositional environments. During the Triassic Period, uplifts in Colorado provided the energy for the alluvial transport of material, covering much of the Canyonlands area with alluvial deposits from the new high country to the east. During the Jurassic Period, mountain building events to the west blocked the flow of moist air over the region, producing a desert/dune environment with wind-deposited sand. These petrified sand dunes comprise the massive cross-bedded sandstone layers that characterize the Canyonlands region. During the Cretaceous Period, seas advanced again and new strata of marine sands, shales and limestones were deposited. These Cretaceous deposits were later completely eroded away in the region of Canyonlands National Park and surrounding areas. Alluvial deposits of the Tertiary Period eroded away, with no

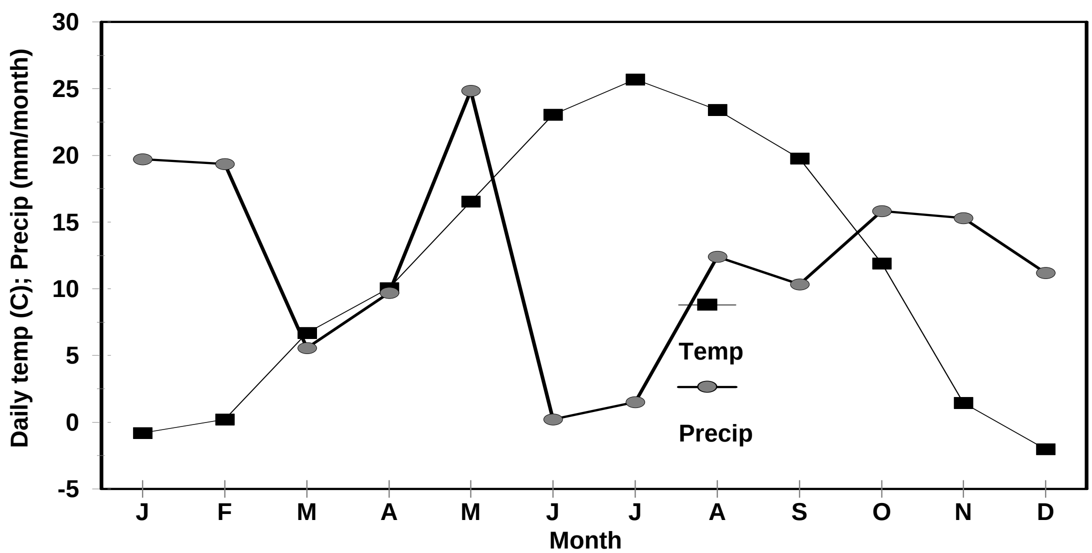
Figure 7-1. Location of Canyonlands National Park.



evidence of their presence in the region. From about 70 to 60 million years ago, the Laramide Orogeny began compressing the Colorado Plateau from the west, uplifting the region and producing monoclines. In the middle Tertiary, the massive uplift of the Rockies provided additional energy to the erosional and alluvial forces that were dissecting the Plateau. The major rivers, the Colorado and Green, set their paths and began to deeply incise the Colorado Plateau (Chronic 1988). In general Canyonlands National Park is covered by bedrock or slightly modified bedrock; soils are sandy and weakly developed.

Climate

The arid climate is characterized by hot, dry summers and cool to cold winters. The Park receives only about 175 mm/yr, with most of the moisture falling during the winter and late summer. Daily temperatures average 25 ^{o}C in the middle of summer, and -2 ^{o}C in winter.

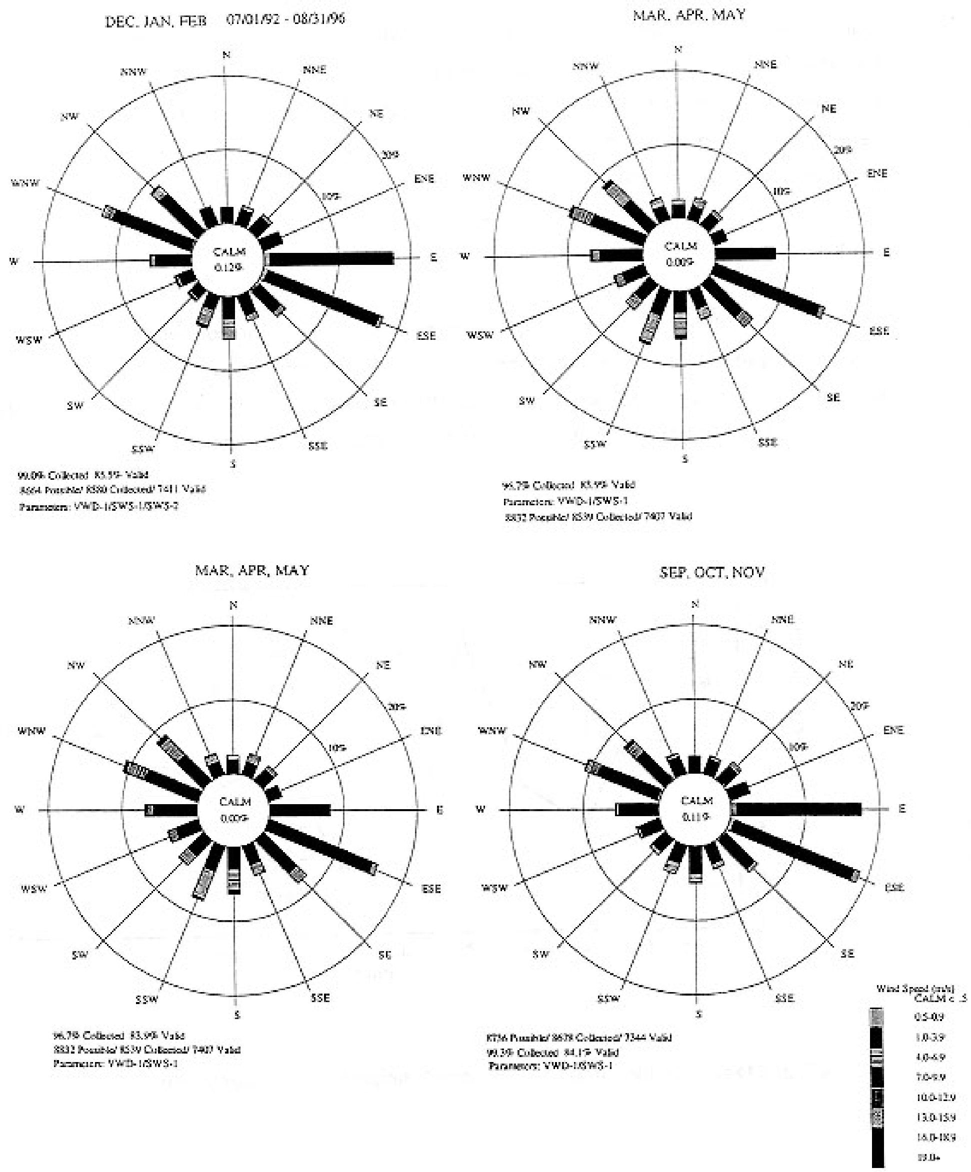


Winds show little seasonal trends; most air comes from the southeast or northwest (Figure 7-3).

Figure 7-3. Wind rose for Canyonlands National Park, 1992-1996.

Canyonlands Air Quality 7-4

Figure 7-3. Wind rose for Canyonlands National Park, 1992-1996.



Vegetation

As with neighboring Arches, geologic substrate and soil type greatly influence the type and distribution of plant communities in Canyonlands National Park (Table 7-1). The dominant vegetative cover types in order of importance are pinyon (*Pinus edulis*)/ juniper (*Juniperus osteosperma*) community which covers about 1/3 of the Park, and includes blackbrush (*Coleogyne ramosissima*), fragrant sumac (*Rhus aromatica*), singleleaf ash (*Fraxinus anomala*), and serviceberry (*Amelanchier utahensis*); blackbrush/Mormon tea (*Ephedra* spp.) shrublands; snakeweed (*Gutierrezia sarothrae*)/ saltbush (*Atriplex* spp.)/Mormon tea shrublands; and galleta (*Pleuraphis jamesii*)/ Indian ricegrass (*Achnatherun hymenoides)* semi-desert grasslands. Large areas of Canyonlands National Park are covered by mixed grasses and microbiotic crusts. Complete species lists for vascular plants in Canyonlands National Park can be found in NPFlora and Welsh (1970), while NPLichen provides a listing of lichen species. There are no known Threatened and Endangered Plant Species or NPS species of special concern (Threatened and Endangered Species Information Institute 1993).

Table 7-1. Distribution of major communities in Canyonlands National Park.

Vegetation type	Landform	Percent of Park area
Snakeweed/Saltbush	Steep talus	13
Snakeweed/Mormon tea	Broken slope	11
Saltbush/cheat grass	Benchland	4
Indian ricegrass/needle&thread grass/blue grama	Mesa	2
Galleta/Indian ricegrass	Bench/terrace/graben	9
Blackbrush/Mormon tea/Galleta	Terrace	20
Sagebrush/saltbush	Alluvial bench	2
Tamarisk/willow	Riparian	1
Pinyon/juniper/cottonwood	Canyon/near riparian	4

Pinyon/juniper	Upland	34

Air Quality

Monitoring of air quality in Canyonlands National Park has included various periods of sampling for ozone and SO_2, and IMPROVE visibility monitoring. The nearest NADP site is Green River, Utah.

Emissions

Table 7-2 provides summaries for emissions of carbon monoxide (CO), ammonia (NH_3), nitrogen oxides (NO_x), volatile organic compounds (VOC), particulate matter (PM), and sulfur oxides (SO_x) for 11 counties surrounding Canyonlands National Park. Most of the high emission of SO_x for Emery County come from the Huntington and Hunter Pacificorp plants. Eatough et al. (1996) apportioned the SO_x in Canyonlands to emission sources over a 3-month period from January through March in 1990, based on “fingerprints” of ratios of compounds in the air, and air mass trajectories. For example, emissions from coal-fired power plants had high ratios of spherical aluminosilicate particles to sulfate, but very low ratios of arsenic to sulfate. Air from Arizona was characterized by low ratios of these aluminosilicate particles to sulfate, and high ratios of arsenic to sulfate. They concluded that SO_x in Canyonlands National Park derived from a wide range of regional sources rather than from a dominant source; about 37% (during a 21 day period) came from the southwest, 20% from the south/southeast, 19% from the north/northeast, and 23% from the northwest. Eatough et al. (1996) concluded that the major sources of SO_x were from the southwest, while major sources of particulate sulfate were from the southeast.

Table 7-2. Emissions (tons/day) for counties surrounding Canyonlands National Park (Radian 1994)

County	CO	NH_3	NO_x	VOC	PM	SO_x
Emery, UT	40	1	114	56	273	51.7
Garfield, UT	14	1	1	63	253	0.2

Grand, UT	17	0	2	47	185	0.2
Kane, UT	15	0	2	44	114	0.2
San Juan, UT	41	1	4	103	405	0.5
Wayne, UT	6	1	1	30	122	0.1
Dolores, CO	4	0	1	10	34	0.1
Mesa, CO	118	3	26	33	197	9.0
Montezuma, CO	35	2	5	18	82	0.6
Montrose, CO	50	2	7	22	95	1.9
San Miguel, CO	11	1	1	11	45	0.1

Air Pollutant Concentrations

The concentrations of ozone from 1992-1994 averaged about 50 ppb, with peak 1-hr concentrations of 65-75 ppb (Table 7-3). These concentrations are near the lower end of the range that may produce visible effects or growth effects on very sensitive species (see Chapter 2). However, no reports of injury or growth effects have been noted. The concentrations of SO_2 were far below any threshold of suggested sensitivity for any plants.

Table 7-3. Concentrations of ozone and SO_2 for Bryce Canyon National Park between May and September. For ozone, upper value is mean daily concentration (ppb); middle number is the maximum 3-month Sum60 exposure (ppb-hr in excess of 60 ppb, 12 hr/day); and bottom number is the maximum 1-hr concentration observed each year. SO_2 24-hr averages from IMPROVE filter samplers (ppb) (1 $\mu g/m^3$ approximately equals 0.38 ppb). Ozone data from the NPS Air Resources Division's Quick Look Annual Summary Statistics Reports (provided by D. Joseph, NPS-ARD).

Year	Ozone	SO_2
1988		
Mean		0.2
Sum60		
Max		0.3
1989		
Mean		0.2
Sum60		
Max		1.1
1991		

Mean		0.3
Sum60		
Max		0.9
1992		
Mean	47	0.1
Sum60	--	
Max	65	0.3
1993		
Mean	47	0.2
Sum60	4156	
Max	75	1.1
1994		
Mean	51	0.2
Sum60	16022	
Max	73	0.4

Visibility

Visual air quality in Canyonlands National Park has been monitored using a transmissometer, aerosol sampler and a camera at locations near the visitor center at Island in the Sky. The transmissometer began operation in January 1987 and the aerosol sampler began operation in March 1988. The camera operated from July 1982 to April 1995. The data from this IMPROVE site have been summarized to characterize the full range of visibility conditions for the period January 1987 through February 1994. The seasons used are: spring = March, April, and May; summer = June, July, and August; autumn = September, October, and November; and winter = December, January, and February.

Optical Data - Transmissometer

The transmissometer system consists of two individually-housed primary components: a transmitter (light source) and a receiver (detector). The atmospheric extinction coefficient (b_{ext}) at any time can be calculated based on the intensity of light emitted from the source and that measured by the receiver (along with the path length between the two). Transmissometers provide continuous, hourly b_{ext} measurements. Weather factors such as clouds and rain can affect transmissometer measurements, but these can be "filtered out" by removing data points with high relative humidities (RH>90%).

The data are presented by season and annual median values, with and without meteorological factors in Table 7-4 Transmissometer Data Summary. The data are presented in units of extinction coefficient in Mm^{-1} and standard visual range in km. Extinction coefficients represent the ability of the atmosphere to scatter and absorb light. Median values with large differences between the extinction values "including weather" and "excluding weather" indicate periods dominated by precipitation. Higher extinction coefficients signify lower visibility. Similarly, season and annual medians with nearly equal "including weather" and "excluding weather" extinctions indicate visibility reduction caused principally by particles.

Table 7-4. Transmissometer data summary for Canyonlands National Park, January 1987 - November 1994. SVR= standard visual range; b_{ext} = light extinction coefficient.

Season Year	Excluding Weather		Including Weather	
	SVR (km)	b_{ext} (Mm^{-1})	SVR (km)	b_{ext} (Mm^{-1})
Winter 1987	125	31	121	32
Spring 1987	118	33	114	34
Summer 1987	161	24	161	24
Autumn 1987	155	25	149	26
Annual 1987	138	28	134	29
Winter 1988	161	24	144	27
Spring 1988	184	21	176	22
Summer 1988	176	22	168	23
Autumn 1988	161	24	155	25
Annual 1988	168	23	161	24
Winter 1989	134	29	129	30
Spring 1989	155	25	155	25
Summer 1989	161	24	155	25
Autumn 1989	176	22	176	22
Annual 1989	168	23	161	24
Winter 1990	193	20	184	21
Spring 1990	161	24	161	24
Summer 1990	149	26	149	26
Autumn 1990	149	26	149	26
Annual 1990	155	25	149	26
Winter 1991	149	26	125	31
Spring 1991	155	25	155	25
Summer 1991	155	25	149	26
Autumn 1991	161	24	161	24
Annual 1991	155	25	149	26

Winter 1992	161	24	76	51
Spring 1992	168	23	161	24
Summer 1992	161	24	161	24
Autumn 1992	134	29	129	30
Annual 1992	149	26	144	27
Winter 1993	129	30	105	37
Spring 1993	144	27	138	28
Winter 1994	256	15	227	17
Spring 1994	184	21	184	21
Summer 1994	161	24	155	25
Autumn 1994	184	21	176	22
Annual 1994	176	22	176	22

No trends were apparent between 1987 and 1994. Visibility tends to be consistently good throughout the year, although high humidity lowers visibility on more days in winter than in other seasons (Table 7-5).

Table 7-5. Standard visual range for Canyonlands National Park. Seasonal averages for median standard visual range in km from January 1987 - November 1994.

Season	Excluding Weather	Including Weather
Winter	163	139
Spring	159	156
Summer	161	157
Autumn	160	156

Aerosol Data

Aerosol sampler data are used to reconstruct the atmospheric extinction coefficient from experimentally determined extinction efficiencies of certain species (Table 7-6). To compare this table with the data from Table 7-4 and 7-5, the "excluding weather" values should be used. In Table 7-6 the data are presented as seasonal and annual 50th and 90th percentile standard visual range for Canyonlands National Park. The 50th percentile means that visual range is this high or lower 50% of the time. This is an average 50th percentile for each season. The 90th percentile means that the visual range is this high or lower 90% of the time. This is an average 90th percentile for each season.

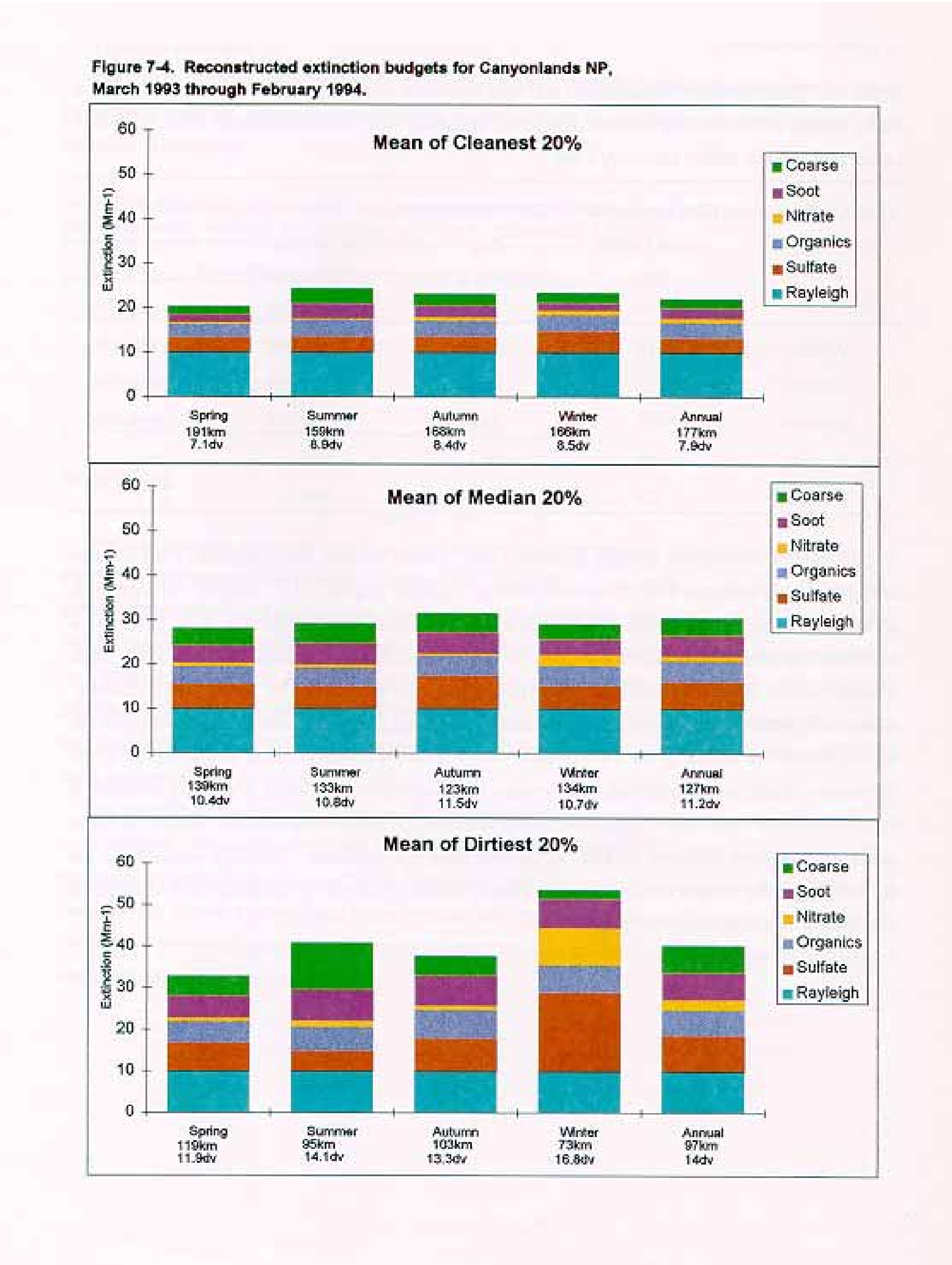
The reconstructed extinction data are used as background conditions to run plume and regional haze models. These data are also used in the analysis of visibility trends and conditions. The measured extinction data are used to verify the calculated reconstructed extinction and can also be used to run plume and regional haze models and to analyze visibility trends and conditions. Because of the larger spatial and temporal range of the aerosol data, the use of the reconstructed extinction data are preferred.

Table 7-6. Reconstructed visual range and light extinction coefficients for Canyonlands National Park, based on IMPROVE aerosol sampler, seasonal and annual average 50th and 90th percentiles, March 1988 - February 1994.

Season/Annual	50th Percentile Visual Range (km)	50th Percentile b_{ext} (Mm^{-1})	90th Percentile Visual Range (km)	90th Percentile b_{ext} (Mm^{-1})
Winter	115	34.0	184	21.3
Spring	143	27.3	193	20.3
Summer	125	31.4	154	25.3
Autumn	130	30.1	182	21.4
Annual	124	31.5	180	21.7

Reconstructed extinction budgets generated from aerosol sampler data apportion the extinction at Canyonlands National Park to specific aerosol species (Figure 7-4). Visibility impairment is attributed to atmospheric gases (Rayleigh scattering), sulfate, nitrate, organics, soot, and coarse particles. The extinction budgets are listed by season and by mean of cleanest 20% of the days, mean of median 20% of the days, and mean of dirtiest 20%of the days. The "dirtiest" and "cleanest" signify days with highest fine mass concentrations and lowest fine mass concentrations respectively, with "median" representing the 20% of days with fine mass concentrations in the middle of the distribution. Each budget includes the corresponding extinction coefficient, SVR, and haziness in dv. The sky blue segment at the bottom of each stacked bar represents Rayleigh scattering which is assumed to be a constant 10 Mm^{-1} at all sites during all seasons. Rayleigh scattering is the natural scattering of light by atmospheric gases. Higher fractions of extinction due to Rayleigh scattering indicate cleaner conditions.

Figure 7-4. Reconstructed extinction budgets for Canyonlands National Park, March 1993 through February 1994.



Atmospheric light extinction at Canyonlands National Park is split fairly evenly among sulfates, organics, soot, and coarse particles. Median and clean day visibility is fairly constant throughout the year. The dirtiest days occur in winter, and are associated with high nitrate and sulfate episodes. In pre-industrial times, visibility would vary with patterns in weather, with winds (and the effects of winds on coarse particles), and smoke from fires. We have no information on how the distribution of visibility conditions at present differs from the profile under “natural” conditions, but the cleanest 20% of the days probably approach natural conditions (GCVTC 1996).

Photographs

Three photos are provided to represent the range of visibility conditions for Canyonlands National Park transmissometer cumulative frequency data (Figure 7-4). The photos were chosen to provide a feel for the range of visibility conditions possible and to help relate the SVR/extinction/haziness numbers to what observers see.

Figure 7-5. Photographs representing visibility conditions at Canyonlands National Park.

Figure 7-5. Photographs representing visibility conditions at Canyonlands National Park.

Canyonlands National Park
on a "clear" day.

Representative Conditions:
Visual Range: 230 - 270 km
b_{ext}: 17 - 14 Mm^{-1}
Haziness: 5 - 4 dv

Canyonlands National Park
on a "average" day.

Representative Conditions:
Visual Range: 100 - 120 km
b_{ext}: 39 - 33 Mm^{-1}
Haziness: 14 - 12 dv

Canyonlands National Park
on a "dirty" day.

Representative Conditions:
Visual Range: 50 - 60 km
b_{ext}: 78 - 65 Mm^{-1}
Haziness: 21 - 19 dv

Visibility Projections

The Grand Canyon Visibility Transport Commission (GCVTC 1996) computer modeling analysis projected likely visibility for Canyonlands through 2040, and the major species responsible for visibility impairment (Figures 7-5, 7-6). Reduced emissions from utilities were projected to reduce light extinction by about approximately 1 Mm^{-1}. Light extinction caused by vehicle emissions was projected to decline until approximately 2005, and then increase through 2040. There is some concern that the modeling completed by the GCVTC may not adequately represent the relative contribution of near and far away sources, because the modeling analysis did not replicate observed conditions well.

Figure 7-6. Projected “baseline” light extinction for Canyonlands National Park (GCVTC 1996).

Figure 7-6. Projected "baseline" light extinction for Canyonlands National Park (GCVTC 1996).

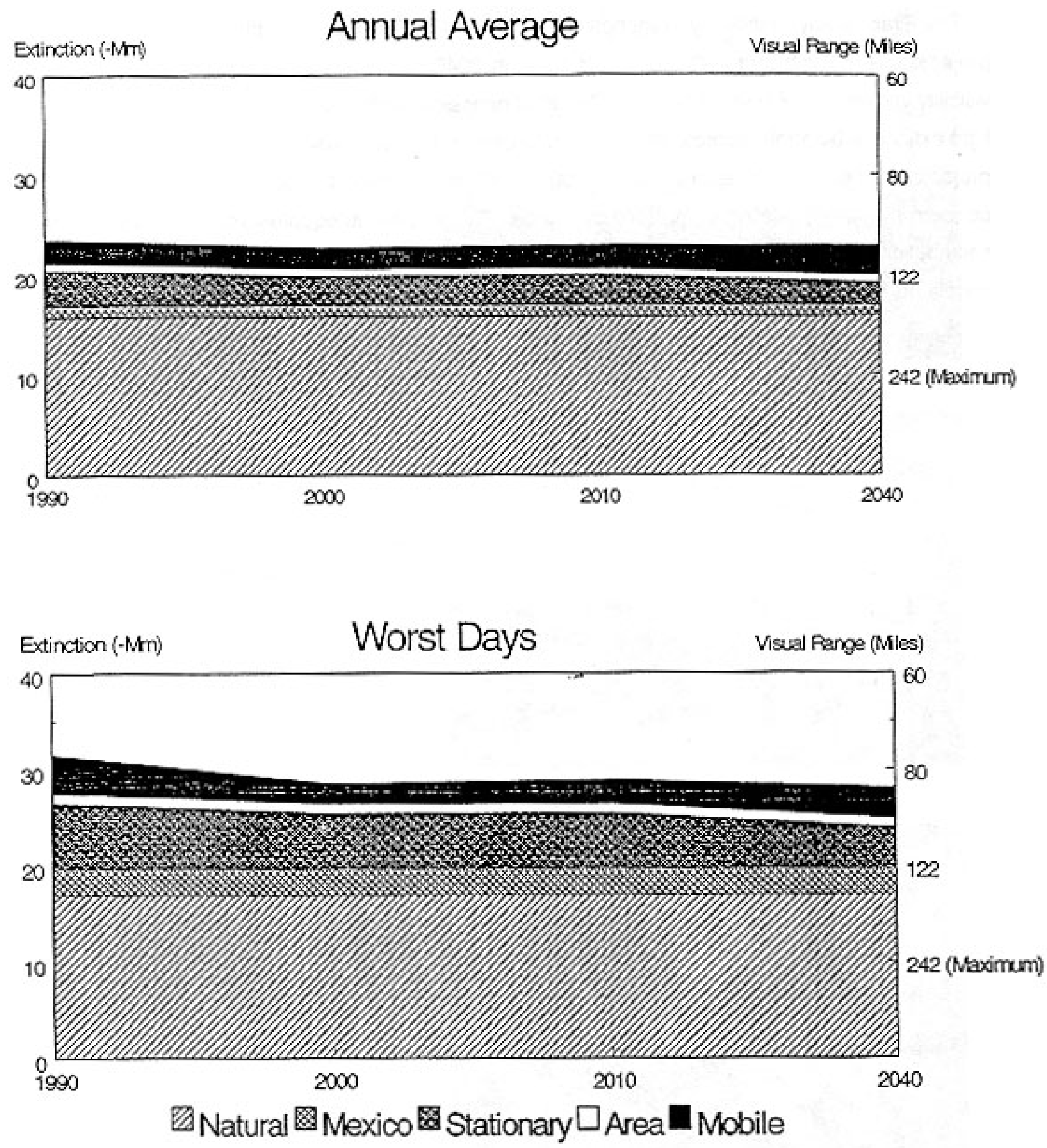
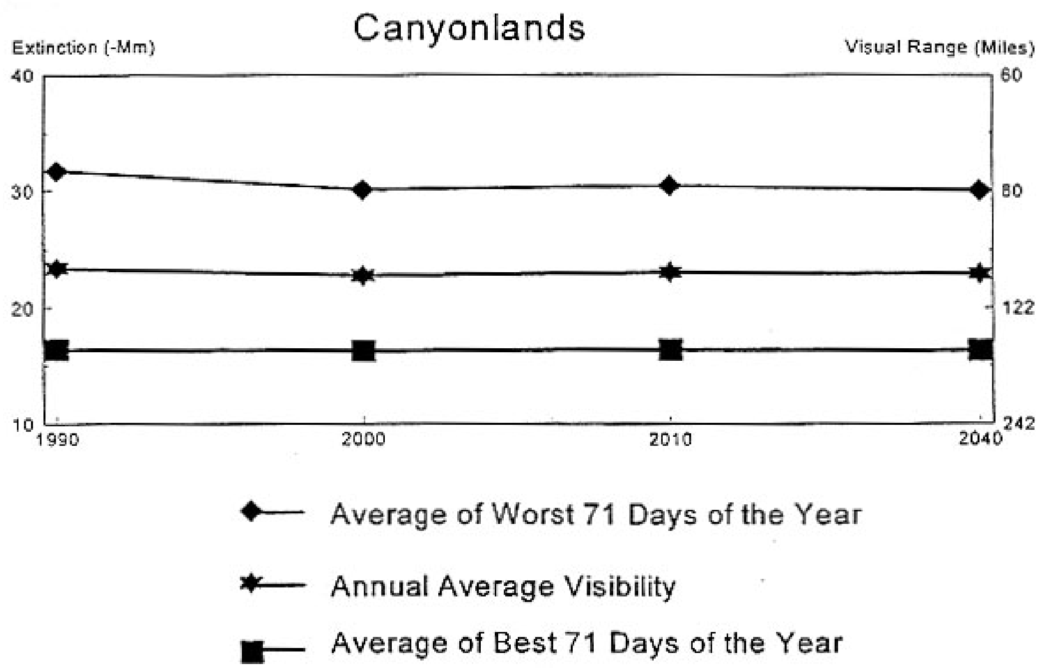


Figure 7-7. Projected "baseline" visibility for Canyonlands National Park for clean, average, and poor visibility periods.

Figure 7-7. Projected "baseline" visibility for Canyonlands National Park for clean, average, and poor visibility periods.



Graph starts at 10-Mm Which is Blue Sky or Rayleigh Extinction.

Atmospheric Deposition

The rates of atmospheric deposition for Green River, Utah (about 70 km northwest of Canyonlands National Park) are relatively low (Table 7-7). Precipitation pH averages about 5.2. Deposition of N averages about 1 kg N ha^{-1} yr^{-1}, which is slightly higher than the rate of S deposition. The deposition of both ammonium and nitrate showed significant increasing trends from 1985 through 1994. Ammonium-N deposition increased by about 0.04 kg N ha^{-1} yr^{-1} (r^2=0.53, $p<0.02$) while nitrate-N deposition increased at a rate of 0.03 kg N ha^{-1} yr^{-1} (r^2 = 0.44, $p<0.04$). However, the significance of these trends depends completely on the very low values for the first year of monitoring (1985) when data completeness averaged only 54%. Even if these values were doubled, we suspect the data would be unreliable, being far lower than any other year. We conclude that N deposition probably has not been increasing at Green River. Sulfate deposition showed no trend during this period. There is no evidence that such low levels of deposition pose any threat to plants (see Chapter 2).

Table 7-7. Atmospheric deposition for Green River, Utah (NADP).

	Concentration (mg/L)			Deposition (kg ha^{-1} yr^{-1})				Conductivity	Precipitation
year	NH_4	NO_3	SO_4	NH_4	NO_3	SO_4	pH	(µS/mm)	(mm/yr)
1985	0.01	0.30	0.49	0.01	0.22	0.37	5.55	0.64	75
1986	0.17	1.19	1.36	0.31	2.10	2.40	5.78	1.57	177
1987	0.48	1.27	1.40	0.86	2.26	2.49	5.35	1.18	178
1988	0.48	1.75	1.47	0.63	2.30	1.94	5.22	1.42	132
1989	0.94	2.13	1.94	0.59	1.35	1.23	6.83	2.68	63
1990	1.00	2.04	2.17	0.66	1.35	1.43	5.82	2.40	66
1991	0.43	1.42	1.22	0.83	2.72	2.34	5.74	1.32	192
1992	0.90	1.50	1.54	1.50	2.51	2.58	5.90	1.54	167
1993	0.53	1.33	1.33	1.10	2.77	2.77	5.58	1.14	208
1994	0.40	1.35	1.05	0.61	2.06	1.60	5.44	1.45	150

Sensitivity of Plants

Sanchini (1983) established sampling plots at Canyonlands National Park, tagging some trees and shrubs for long-term monitoring of possible pollutant impacts. She focused on pinyon pine, single-leaf ash, and Utah serviceberry. No symptoms of damage from any air pollutant were observed on these plants nor on any other she examined (including crustose and foliose lichens).

No visible injury signs of air pollution damage have been reported for vegetation in or near Canyonlands National Park. Only a few of the Park's species have been tested under controlled conditions for sensitivity to pollutants, and none of these tests included genotypes representative of the plants in the Park. Based on the ozone concentrations required to affect very sensitive plants, we expect that current ozone exposures could be high enough to affect some species. Current levels of ozone are probably too low to affect the conifers, and levels of SO_2 are far below any demonstrated threshold of sensitivity for any plants. In the absence of empirical evidence of any effects, no substantial problem is likely.

Water Quality and Aquatic Organisms

No information is available for water quality or aquatic ecosystems for Canyonlands National Park. Because of the proximity to Arches we would expect that rock pools found in Canyonlands would be similar in chemistry and biological communities to those found in Arches.

Recommendations for Future Monitoring and Research

General recommendations for NPS Class I areas of the Colorado Plateau are presented in Chapter 14, and many of these apply to Canyonlands National Park. We recommend that Park staff review bedrock geology maps to determine regions of rock resistant to weathering, and begin to characterize water chemistry and sensitivity to deposition. If rock pools or tinajas occur in these areas of sensitive bedrock, we recommend that water samples be collected in different seasons of the year to determine pH, ANC, and conductance of these waters. If pH values are near 6.0 or less, or ANCs are less than 200 ueq/l, then major anions and cations should be measured. Once sensitivity is determined for selected waters, then a monitoring program can be designed to look for both chronic and episodic changes in chemistry that might be affected by changes in deposition.

Park Summary

Visibility is currently the only AQRV known to be impacted by pollution at Canyonlands National Park, as with the other Class I NPS areas of the Colorado Plateau. Current levels of pollution in southern Utah are high enough to produce haze and obscure the important vistas of Canyonlands National Park and surrounding areas. Any increase in aerosols will undoubtedly impair visibility further; substantial reductions in aerosols would be needed to restore pristine conditions at Canyonlands National Park.

Little information has been collected on air pollution effects on the Park's biota. No sign of air pollution impacts on plant or animal species has been reported; ozone concentrations are high enough that some impact is possible for sensitive plants, but SO_2 concentrations are too low to affect plants.

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